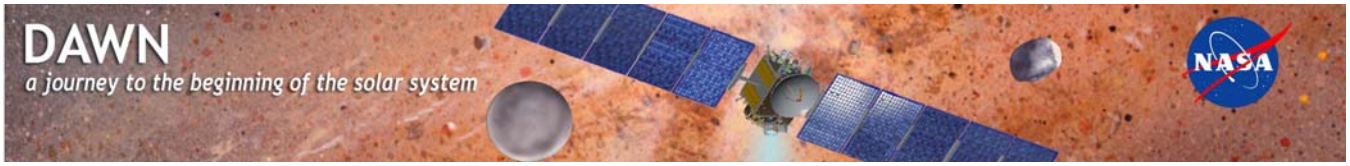
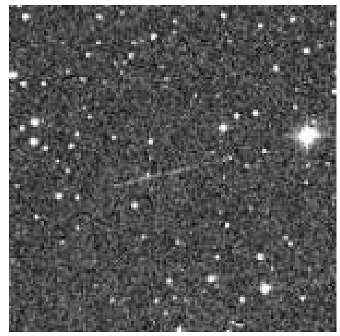


What CAN You See With a Telescope?

The four principal asteroids—Ceres (see “It Was a Dark and Starry Night”) Pallas, Juno, and Vesta (see “Astronomical Serendipity”)—were discovered between 1801 and 1807. No additional asteroids were found until 1845—almost forty years later—even though groups of amateur and professional astronomers designed special sky-mapping projects to search for them.

A Lull in Asteroid Discovery

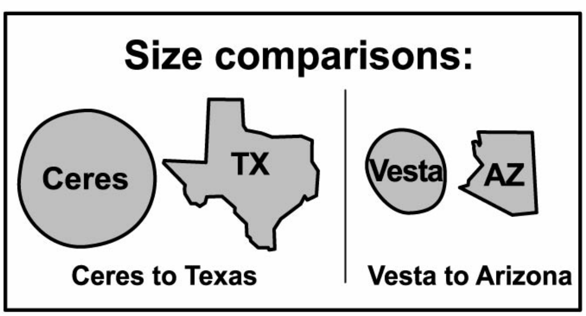
Why were no new asteroids found during this period? Simply put, most of them were too small and too dim to be easily observed through the early 19th-century telescopes. Remember that many of the early asteroid discoverers were amateur astronomers using very modest equipment. And they were looking for asteroids that were much smaller and/or dimmer than the four principal asteroids that had already been found. Even when the four largest asteroids were seen through those telescopes, they appeared only as points of reflected sunlight (see “Of Glass and Light”). They looked very much like the countless stars around them, except that they moved. If you want to experience the difficulty of searching for a moving point of light in a sky full of stars, try out the “In Search Of…” activity.



Can you find the asteroid amidst all these stars? The faint streak in the center is the trail left by a moving asteroid. This one, captured by the Palomar Digital Sky Survey, is asteroid 1999 AN10.

http://www.jpl.nasa.gov/news/features.cfm?feature=536

Size a Factor in Asteroid Discovery



Ceres, the largest asteroid, measures about 960 km at its longest axis. Pallas’ longest axis is about 574 km. Vesta is about half the size of Ceres, with its longest axis measuring about 560 km. Juno is the smallest of the principal four; its longest axis is approximately 190 km.

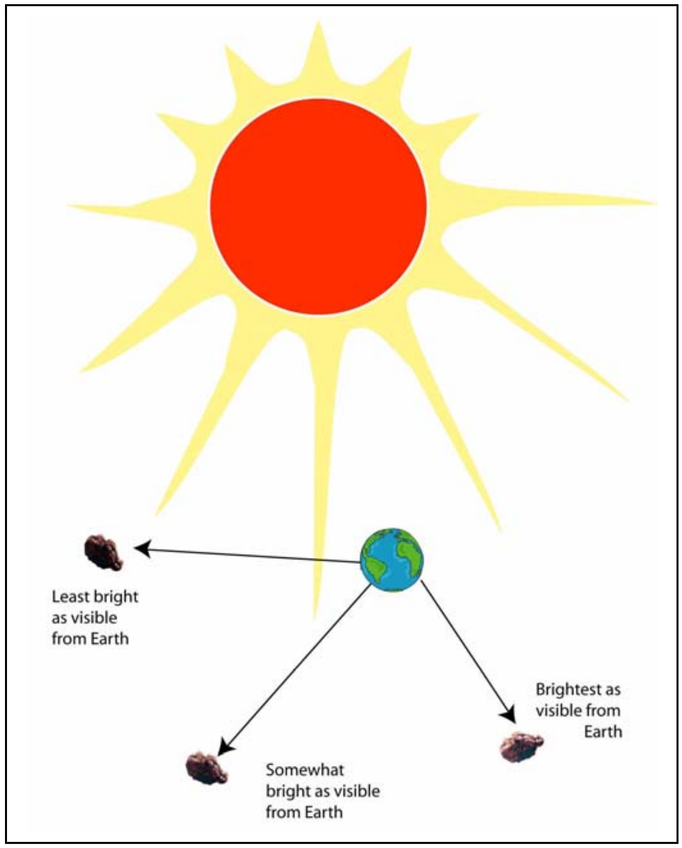
n 1802, William Herschel (see “Astronomical Serendipity”) attempted to measure the size of Ceres and Pallas by looking at the asteroids through a telescope with one eye and comparing them to a small disk of a known size at a given distance. Herschel’s estimated values of 259 km for Ceres and 236 km for Pallas were considerably smaller than the modern measurements given above.

Most of the asteroids discovered between 1845 and 1890 ranged in size between 80 and 130 km, much smaller than the principal four. Hygiea, found in 1849, is an exception with a diameter of about 410 km, but it is dimmer than any of the principal four. To date a total of only about 30 asteroids with diameters greater than 200 km have been found. It is estimated that there are 250 asteroids larger than 100 km in diameter and perhaps 1,000,000 with diameters greater than 1 km.

Asteroid Brightness—Another Factor to Consider

So, the size of the vast majority of asteroids is quite small, but that is not the whole story. An asteroid's brightness varies according to its orbital position and its *distance* from Earth. Since most asteroids have very irregular shapes, their brightness is also dependent upon which part of their surface is facing the sun, and the reflective power or **albedo** (see Dawn Dictionary) of the reflecting surface.

The table below shows the *brightest* attainable **magnitude** for the first ten asteroids, which is usually during "**opposition**" (see illustration to the right); that is, when the asteroid is opposite the sun as seen from Earth. Brightness is measured on a scale in which the larger the value of an asteroid's brightness, the dimmer the asteroid appears to an observer on Earth.



Note that Ceres and Vesta have almost equal apparent brightness, 4.0 and 4.2 respectively, but they are quite different in size, distance, and **albedo** or how much light they reflect.

- Ceres is about twice the size of Vesta.
- Vesta, with a **semi-major orbital axis** (SMA) of 2.36 AU (see Dawn Dictionary), orbits slightly closer to the Earth than does Ceres, whose SMA is 2.77 AU.
- Vesta's surface **albedo** is 0.42, which means that it reflects four times more light than Ceres' surface with an **albedo** of 0.11.

Asteroid Number	Year of Discovery	Asteroid Name	Brightest attainable magnitude	Asteroid Number	Year of Discovery	Asteroid Name	Brightest attainable magnitude
1	1801	Ceres	4.0	6	1847	Hebe	8.5
2	1802	Pallas	5.1	7	1847	Iris	8.4
3	1804	Juno	6.3	8	1847	Flora	9.0
4	1807	Vesta	4.2	9	1848	Metis	9.8
5	1845	Astraea	6.6	10	1849	Hygeia	6.4

Asteroids are now numbered in the order in which they were discovered, so you can see that the relative brightness of the principal asteroids, 1 Ceres through 4 Vesta, may have been a factor in their early discovery. Even 1 Ceres, the brightest asteroid, is only a moderately bright star when seen through a telescope. The brightness of most asteroids is below the 10^{th} magnitude, so they look like faint stars.

To put these asteroid brightness measurements into perspective, the Sun has an apparent magnitude of -27, the Moon -12, Venus -4, and the brightest stars are –1. An object of approximately the 6th magnitude, like 3 Juno, is barely visible to a person with good eyesight on a clear, moonless night. With a good set of binoculars, one can see objects down to the 10th magnitude. With an 8-inch reflecting telescope an observer can manage to see objects of 14th magnitude on very dark nights (see http://www.geocities.com/catskills_astronomy_club/darksky.htm). The faintest objects detectable with the largest ground-based telescopes are about magnitude 30.

Rotation Rates Influence Asteroid Brightness

Early astronomers had used their telescopes to measure the **rotation rate** (see Dawn Dictionary) of the Sun and some of the planets. Since the asteroids were thought to be "minor planets," it was assumed that they also rotated on their own axes. In 1810, Schöeter (see "Astronomical Serendipity") thought he detected a 27-hour rotation rate for 3 Juno, which is about four times the current value of 7.21 hours. An asteroid's rotation rate is determined by measuring the short-period fluctuations or variations in brightness. As an asteroid rotates on its axis, its irregularly-shaped body and the different albedos of its reflecting surfaces cause changes in brightness. For asteroids, these variations are small— as small as a few hundredths to 0.4 of a magnitude—and difficult to detect except under ideal conditions.

So, the only asteroid features that early 19th-century astronomers could observe with their telescopes were dependent upon the brightness and the variations in brightness of their reflected light. And, recall these asteroids appeared only as points of light through the telescopes available during that time period. Obviously they could not see any surface feature details of even 1 Ceres or 4 Vesta, the largest and the brightest of them all.

Additional Resources

Web Sites

http://near.jhuapl.edu/NEAR/Voyage/img/lcurve3.mpg
This animation shows the brightness variations of asteroid Eros during its rotation. Observe closely or you may miss this flashing point of light.

For more information about the history of the brightness scale, go to:
http://www.astro.virginia.edu/~teacha/130_manual/node30.html or
http://www.astro-tom.com/technical_data/magnitude_scale.htm

http://www.astro.uu.se/planet/asteroid/shapes/
This interactive allows the user to rotate irregular-shaped asteroids to see how they would look in 3-D.

Print Resources

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Peebles, C. (2000). *Asteroids: A history*. Washington, DC: Smithsonian Institution Press.

Roth, G. D., (1962). *The system of minor planets*. Princeton, NJ: Company Inc.